OBSERVATIONS ON ANTS IN THEIR RELATION TO TEMPERATURE AND TO SUBMERGENCE.

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Although this paper finally treats of measures for the extermination of ants, the experiments[1] herein recorded were begun with a view to ascertaining the temperature preferred by ants and conducing to their rapid development in artificial nests.

The ants employed were *Lasius latipes*, yellow, translucent ants, from four to five millimeters long; *Stenamma fulvum*, brown ants, from six to seven millimeters long; *Camponotus pennsylvanicus*, black ants with dense integument, from eight to eighteen millimeters long. The ants were chosen with reference to color and size, a colony of *Camponotus* whose members varied exceedingly in stature having been previously captured.

A special nest was made, affording opportunity for the ants to choose temperature agreeable to them. It consisted of a copper[2] half-cylinder, three centimeters in diameter, in which the central portion of the interior, one meter or forty inches in length, was partitioned from the further extending ends, lined with white blotting paper apart from the copper, and imbedded, concave side upward, in cotton wadding which extended slightly over the edges of the half-cylinder at its sides. The half-cylinder was made level, so that gravity should not influence the behavior of the ants. The central portion was kept dry throughout, that the influence of humidity might be eliminated. It was covered with glass microscope-slides laid transversely, and topped with blotting paper so as to secure uniform darkness within. The layer of wadding between the edge of the copper and the glass roofing admitted sufficient air for the ants to breathe, and left no interstice for their exit.

At the right-hand end the bare copper extended beyond the supporting table and was heated by an alcohol flame. At the

[1] These experiments were made at the Marine Biological Laboratory, Woods Holl, Mass., in June, 1904.

[2] Material suggested to me by Dr. G. H. Parker.

left-hand end the bare copper was surrounded by ice. When all was established, the interior surface of the nest, tested by removing a slide and covering the aperture with a wad of cotton through which passed a centigrade thermometer, showed a range of temperature from 10° C. or 14° F. at the left-hand end to 60° C. or 140° F. at the right-hand end. The air was usually a degree or two lower than the enclosing surface that warmed it.

I then separately introduced into this nest different groups of the above-named genera, workers, larvæ and pupæ, in each case leaving the group to collect its scattered young at whatever portion of the nest the workers should themselves select. With great unanimity the different groups chose a place in the nest where the temperature was from 24° to 27° C. or 76° to 82° F., the temperature being taken from the surface against which the ants and young rested.

This is the temperature at which I have observed greatest activity and reproductivity in my artificial nests. I have also, when the temperature of the air was somewhat below 22° C. or 70° F. repeatedly observed wild colonies of *Stenamma fulvum*, where the larvæ and pupæ had been carried outside the nest and laid among the grass stems for greater warmth, despite the daylight from which the ant-nurses commonly withdraw the young.

In 1901 I froze[1] *Stenamma fulvum*, queens, workers and young, for twenty-four hours, the thermometer going down to − 5° C. or 23° F. The ants were gradually thawed and all survived. The frozen eggs, larvæ and pupæ developed perfectly later on.

Below 15° C. or 60° F. the ants are noticeably sluggish. Increase of activity accompanies increase of temperature from freezing point, where they are wholly inert and apparently lifeless, up to a degree where they swoon from the intensity of the heat. In the copper nest the ants manifested discomfort or distress at any temperature above 30° C. or 86° F. At 35° C. or 96° F. the smallest ants swooned, and I could induce no ant to voluntarily move to a hotter portion of the nest, even when driven by sun-

[1] "A Study of an Ant," *Proceedings of the Academy of Natural Sciences of Philadelphia*, July, 1901, p. 441.

light or when in pursuit of scattered larvæ which are commonly sought with self-sacrificing assiduity.

When the largest ants were introduced into the rest where the temperature was between 40° C. and 50° C. or 105° F. and 122° F. they either succumbed to the heat and swooned upon the floor or else struggled away toward the cooler end of the nest. All ants that swooned and fell where the temperature was below 50° C. recovered their activity if soon removed to cool and humid quarters. Ants exposed for two minutes to a temperature of 49° C. revived after some hours and resumed their normal occupations.

But exposure to heat so great as 50° C. or 122° F. produces in the ant pathological conditions from which it does not recover if the exposure is sufficiently prolonged. Probably the protoplasm of the ant coagulates at 50° C., the time required for the coagulation of all the protoplasm depending on the size of the ant. The time is the same for ants of the same size and species, whether the heat be imparted through a dry or a wet medium.

In order to ascertain the time required for the heat to kill the ants, I adopted a method which produced no mechanical injury. Grasping one or more legs of the ant with padded forceps, I merged the ant in air or water heated to just 50° C. and held it there for the recorded number of seconds, then laid it upon a cool moist sponge, to remain under observation during the five ensuing days or longer. Every ant appeared to die as soon as it reached the heated medium.

The first sign of revival, a slight twitching of the legs, was sometimes given many hours or even a day or two after the exposure to the heat. That these throes were those of returning rather than of departing life was proven by the complete recovery of some of the ants after days of manifest illness, abstentation from food and indifference to environment. Many ants revived that never wholly recovered.

Whenever any ant gave evidence of life, I provided hygienic conditions and trained nursing. Recuperation was slow in proportion to the length of time the ant had been exposed to the heat. One *Stenamma* that had been exposed twenty seconds, gave the first sign of returning life forty-seven hours later, and

died within a day. Another *Stenamma* revived forty-three hours after the same exposure and lived at least seven days. One *Camponotus* gave the first sign of returning life fifty-seven hours after its exposure of one minute to the heat and was more than a week in convalescence.

Lasius latipes. — When exposed ten seconds to heat at 50° C. twenty-three per cent. revived. When exposed for fifteen seconds none revived.

Stenamma fulvum.—When exposed to a temperature of 50° C. for ten seconds, forty per cent. revived; when exposed for fifteen seconds, fourteen per cent. revived; when exposed for thirty seconds none revived.

Camponotus pennsylvanicus.—When exposed to temperature of 50° C. for thirty seconds, all revived; when exposed for one minute, fifty per cent. of those of the largest stature revived; when exposed for two minutes, none revived.

Throughout the experiments, the smaller ants succumbed under the shorter exposures, while the larger ants were those that survived the longer exposures; but a temperature of 50° C. sooner or later proved fatal to all.

Submergence in Cool or Cold Water.

That the ants were killed by the heat and not by asphyxiation, when the medium was water, was shown by the fact that the ants succumbed during a like period of exposure whether in water or in air equally heated. But I tested the effect of submergence in cool or cold water and found that the ants survived such submergence for comparatively immense periods.

When ants are submerged they struggle or crawl about for a few minutes only, after which they sink and appear to have died. Many groups of ants were submerged with the following results:

Lasius latipes: Group a. — Fifty per cent. revived after twenty-seven hours' submergence and were alive and well six days later. The revivals all occurred within two hours after the ants were removed from the water to a moist sponge.

Stenamma fulvum: Group b. — All revived after eighteen hours' submergence.

Group c. — Seventy-five per cent. revived after fifty-two hours' submergence, and were alive and alert two days later.

Group d. — Fifteen per cent. revived after seventy-two hours' submergence, the first sign of revival appearing six hours after removal from the water. These survivors lived several days, but never resumed their normal activities.

Group e. — None survived eighty-eight hours' submergence.

Camponotus pennsylvanicus : Group f. — Thirty-three per cent. revived after forty-eight hours' submergence, and fully recovered. The first sign of revival was given twenty hours after removal from the water, and recovery occupied many ensuing days. The ants were about fifteen millimeters in length.

Group g. — Fifty per cent. revived after seventy hours' submergence, the first signs of revival being given from twenty-one to thirty hours after removal from the water. Full recovery did not occur until after a lapse of many days : but twenty-five per cent. were returned alive to a nest, where they met and were met by their former comrades, with manifest pleasure.

Group h. — Only ants from fifteen to eighteen millimeters in length were employed. After a submergence of ninety-five hours, none revived.

Such results show the futility of ploughing up ant-nests and exposing the ants to spring rains as a means of exterminating these pests on the farm. They indicate for this object the application of heat to the nests, through any medium wet or dry, the degree of heat being no less than 50° C. for any ants, and the duration of the application being at least fifteen seconds for the smallest ants and two minutes for large ones. Lured by greater warmth, the ants assemble with their young at or near the surface of the ground early in summer, and they would be surely destroyed either by shoveling the nests, with their millions of developing young, into a hot portable oven, or by saturating the nests *in situ* with water duly heated. The ants that injure growing crops by pasturing the aphides, their "milch cows," upon the roots and stems, are small ones, and they would probably be killed by an application of water hot enough to destroy the ants without injury to the plant.

The great tenacity of life in the ants and the distress evinced by them during slow recovery or dissolution, should impel those undertaking their extermination to do the work speedily and effectually.